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The shared neural basis of empathy and facial imitation accuracy

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ABSTRACT

Empathy involves experiencing emotion vicariously, and understanding the reasons for those emotions. It may be served partly by a motor simulation function, and therefore share a neural basis with imitation (as opposed to mimicry), as both involve sensorimotor representations of intentions based on perceptions of others' actions. We recently showed a correlation between imitation accuracy and Empathy Quotient (EQ) using a facial imitation task and hypothesised that this relationship would be mediated by the human mirror neuron system. During functional Magnetic Resonance Imaging (fMRI), 20 adults observed novel 'blends' of facial emotional expressions. According to instruction, they either imitated (i.e. matched) the expressions or executed alternative, pre-prescribed mismatched actions as control. Outside the scanner we replicated the association between imitation accuracy and EQ. During fMRI, activity was greater during mismatch compared to imitation, particularly in the bilateral insula. Activity during imitation correlated with EQ in somatosensory cortex, intraparietal sulcus and premotor cortex. Imitation accuracy correlated with activity in insula and areas serving motor control. Overlapping voxels for the accuracy and EQ correlations occurred in premotor cortex. We suggest that both empathy and facial imitation rely on formation of action plans (or a simulation of others' intentions) in the premotor cortex, in connection with representations of emotional expressions based in the somatosensory cortex. In addition, the insula may play a key role in the social regulation of facial expression.

Introduction

Facial expression is one of the most important ways in which people communicate. It involves expressions modified through social learning, and so develops through imitation involving the voluntary and intentional matching of behaviours (Bekkering et al., 2000; Wohlschläger et al., 2003). Imitation differs from mimicry which requires no modification of previously learnt behaviour (Provine, 2010; Yoon and Tennie, 2010) as it requires an understanding of the relationship between another person's actions, intentions and goals compared to one's own motor repertoire, to permit novel learning and expansion of a behavioural repertoire (Whiten, 2006). It follows that effective imitation of an emotional expression should require the observer to have some understanding of the relationship between the motor plan for the expression (Carpenter, 2006) and the underlying emotional state that the expresser may want to convey. In this sense, we would expect facial imitation to draw upon empathic mechanisms.

It has been suggested that both imitation (e.g. Leslie et al., 2004; Williams et al., 2007) and empathy (Gallese and Goldman, 1998) involve the mirror neuron system (MNS; e.g. Rizzolatti et al., 1996). This action–perception matching mechanism is thought to be based in the inferior frontal gyrus (IFG), inferior parietal lobe and premotor cortex (Gallese et al., 1996; Molenberghs et al., 2012), though somatosensory cortex has also been implicated (Keysers and Gazzola, 2009). In a review of some 200 functional Magnetic Resonance Imaging (fMRI) studies that restricted its regions of interest to anterior intraparietal sulcus and premotor cortex, Van Overwalle and Baetens (2009) found that the MNS is engaged during perception or execution of articulated motions of body parts and argued that this confirms the self–other matching role of the MNS in understanding biological action. Therefore whilst there is little controversy as to whether the MNS plays a role in imitation, its role in empathy is much less clear. Meta-analyses of studies that elicit empathy during fMRI (Fan et al., 2011; Lamm et al., 2011) find consistent activation of the insula bilaterally, as well as the anterior dorsal and mid cingulate cortex extending into the supplementary motor area (SMA). They have not identified the MNS in empathic function in the absence of action observation (though SMA is arguably part of the human MNS since it has consistently been shown to be active during action observation and imitation — Caspers et al., 2010). Other reviews (Bastiaansen et al., 2009; Decety, 2011; Kurth et al., 2010) have also noted the importance of the insula and a lack of evidence for direct mirror system involvement in empathy. Nevertheless, some studies have implicated the MNS in empathy. Carr et al. (2003) found that

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both imitation and observation of emotional expressions activated premotor areas and suggested that we understand what others feel by a mechanism of action representation. Pfeifer et al. (2008) found a correlation between empathic traits in 10 year olds and inferior frontal gyrus activity during imitation. Cheng et al. (2009) found correlations between grey matter volume in mirror neuron areas and empathic traits, suggesting that the MNS is important for the development of empathic traits as well as imitation. Schulte-Ruther et al. (2007) asked participants to look at emotional expressions and ask 'how do I feel?' or 'how does he feel?' In voxels identified through a conjunction analysis of both conditions, the activity correlated with empathic traits in posterior Superior Temporal Sulcus (pSTS) as well as IFG.

The way that empathy is defined is relevant. It may be defined as the capacity to understand other people's feelings and respond to them appropriately (Baron-Cohen and Wheelwright, 2004), though it is also appreciated to be a multifaceted concept (Decety, 2011), and many authors argue for categorising types of empathy. For example, whilst Baron-Cohen and Wheelwright (2004) proposed a single factor model of empathy that relies on both perception and understanding, Muncer and Ling (2006) identified 3 factors of cognitive empathy, emotional reactivity and social skills. In addition, empathic personality traits may be distinguished from empathy as a state of mind. De Vignemont and Singer (2006) restrict their definition of empathy to a conscious affective state that is isomorphic to another person's affective state, elicited by the observation or imagination of that person's affective state, with awareness that the other person is the source of this affective state. They see affect-sharing but not cognitive perspective-taking as essential to empathy. This framework has informed the design of those studies that have not found MNS involvement in empathy. However, this model of empathy is rather similar to that of emotional contagion (Hatfield et al., 1993), which in turn is akin to mimicry.

The processes involved in emotional contagion as a passive experience are likely different from more active attempts to understand what someone is feeling when they show novel or ambiguous behaviour. Then one can 'simulate' the other's mental state (Gordon, 1996). Simulation theory of mind could be considered a descendant of ideomotor theory (Greenwald, 1970; James, 1890; Shin et al., 2010). This argues that the perception of an action 'awakens' the corresponding motor plan for that action, which, by drawing upon an experience of stimulus–response associations, can then be internally rehearsed without enacting, thereby enabling one to anticipate the next action in the sequence, predict what the other person is feeling and generate an understanding of intention. An ideomotor or simulation form of empathy is more akin to imitation, and thereby utilises sensorimotor representations which can be altered through new learning as actual outcomes differ from anticipated ones. In keeping with this argument, the studies cited above suggest that the human MNS becomes associated with empathy when tasks require more active engagement such as through imitation rather than just passive experience.

Behavioural studies of imitation ability have shown little in the way of a relationship with empathic traits. Two possible reasons for this may be considered. One is that imitation studies tend to explore manual actions rather than emotion. Secondly, those studies that do use emotional actions only examine imitation of stereotypical expressions, which do not place sufficient demand on those cognitive capacities that are specific to imitation. Studies of imitation have relied on the 'do-as-I-do' method of measuring imitation accuracy (e.g. Hamlin et al., 2008), whereby the amount of difference between the attempt and the model is quantified. While this approach is straightforward for simple and qualitatively distinct actions, everyday facial imitation is both emotionally communicative and demanding of subtle shifts in emotional expression. In theory, the Facial Action Coding System (FACS; Ekman and Rosenberg, 1998) could be used to deconstruct a facial action, but not only is it labour and time intensive, it describes an expression in terms of multiple variables making comparisons complicated. An alternative measure of imitation accuracy consists of examining whether individuals show evidence of discrimination between subtly different actions by the way that they re-enact these demonstrated actions (Braadbaart et al., 2012; Williams et al., 2013b). For a series of actions, imitation accuracy can then be reflected by a rank correlation coefficient between the model and participant's performance across trials.

We extended the principle of quantifying imitation accuracy to facial expression of emotion by designing a novel set of stimuli, using composites of the six basic emotions (happiness, fear, anger, surprise, sadness and disgust; e.g. Elfenbein and Ambady, 2002). These composites were created by systematically blending three basic emotional expressions in controlled proportions so that they formed two triangular arrays of 15 stimuli each (see Fig. 1 for example). This meant that each stimulus differed from each other by a quantifiable amount. Imitation accuracy could then be determined by how well photo-captures of imitation attempts allowed reconstruction of the original triangular expression arrays (see "Behavioural imitation tasks" section). Williams et al. (2013a) used these emotional 'blends' to discover that the accuracy measure of emotional expression correlated with score on a self-report measure for empathy, the Empathy Quotient (EQ; Baron-Cohen and Wheelwright, 2004). The relationship between EQ and facial imitation ability could be explained in several ways. We hypothesised that facial imitation may serve as a proxy measure of empathy (Carr et al., 2003; Leslie et al., 2004), with both functions mediated by common cognitive control mechanisms based within the mirror neuron system (Bastiaansen et al., 2009; Decety, 2011; Iacoboni and Dapretto, 2006). Other mechanisms to consider were: (a) social motivation associated with the orbitofrontal cortex; (b) an inferential Theory of Mind mechanism based in the right temporoparietal junction and medial prefrontal

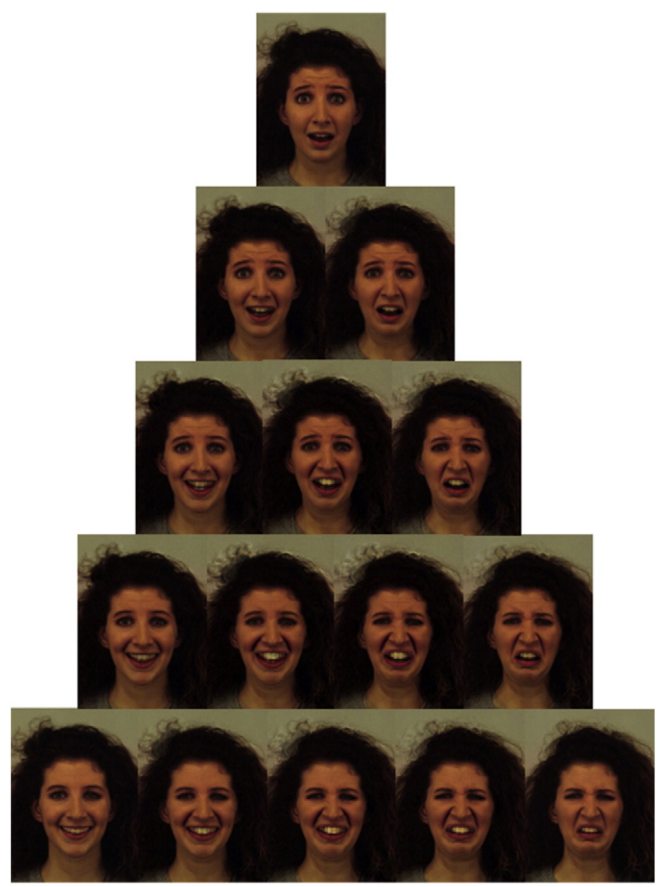

Fig. 1. Example of a Fear–Happiness–Disgust triangle, whereby the apices of the triangle show the three emotions expressed to 110%, and every other image represents increasingly mixed facial expressions, combining two or three emotions to create new images depending on the location of the image within the triangle.